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ANGULAR SIGNATURES, AND A SPACE-BORNE MEASUREMENT
CONCEPT

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Angular Signatures, and a Space-borne Measurement Concept

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ABSTRACT

The nature and value of angular signatures in remote sensing are reviewed with emphasis on the canopy hot-spot as a directionally localized angular signature and an important special case of a BRDF. A new concept is presented that allows hot spot measurements from space by using active (laser) illumination and bistatic detection. The detectors are proposed as imaging array sensors that are circulating the illumination source (or vice versa) and are connected with it through tethers in space which also provide the directional controls needed so that the entire system becomes pointable like a search light. Near infrared or IR operation in an atmospheric transmission window is envisioned with night-time data acquisition. Detailed feasibility and systems analyses have yet to be performed.

INTRODUCTION

Every remote sensing instrument measures radiation that is expected to be related to a physical feature of the remotely sensed object; the data is then called a signature. Typically, when a surface scene is the object of the remote measurement, the measured radiance is the result of reflected or emitted radiation which may vary with the wavelength of the radiation and is then called a spectral signature. Similarly, spatial, temporal, angular and polarization reflectance signatures can be identified [1], as shown in Fig. 1.

An angular signature requires observations from different view directions. Airborne and satellite remote sensing systems that operate only at nadir, for example, are incapable of recording angular signatures. Some developmental instruments, such as ASAS and PARABOLA, and future EOS detectors, such as MISR, do measure angular signatures requiring that models are developed that relate the measured data to the physical surface feature [2].

ANGULAR SIGNATURES

All structured (three-dimensional) surfaces, such as vegetated surfaces or sloped terrain with varying elevations within a scene, exhibit angular signature effects. A Bidirectional Reflectance Distribution Function (BRDF) may be considered the most general form of an angular signature. BRDFs of vegetated surfaces, whose architecture always is three-dimensional in nature and where the reflected radiation is therefore dominated by internal shadowing effects, usually show large variabilities in their values across the

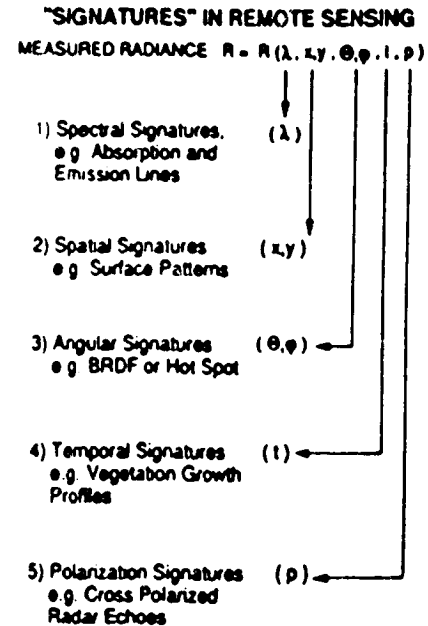


Figure 1: Five characteristic reflectance signatures in remote sensing.

hemisphere. A typical example is reproduced from BRDF measurements taken by Kriebel [3] from an aerial platform over grasslands, which are probably the earliest fairly complete angular signature data taken of that kind. The data for 3 different BRDF slices through the principal plane under 3 different solar illumination conditions, are shown in Figure 2 as an illustration.

THE CANOPY HOT SPOT

A prominent component of every BRDF of a structured surface is its internal shadowing that depends on illumination and observation directions, and on the internal structure (architecture) of the 3D surface. The structural information about a vegetation canopy, e.g., is not expressed in either the spatial or spectral signatures of the canopy, but solely in its angular signature. It has been shown that leaf size and canopy height can be retrieved from a special/local angular signature, the canopy hot spot, in particular from its angular width [4]. Figure 3 shows 2 examples of hot spot photographs taken from an airplane with standard panchromatic film in the visible. Additional such data are shown in [4].

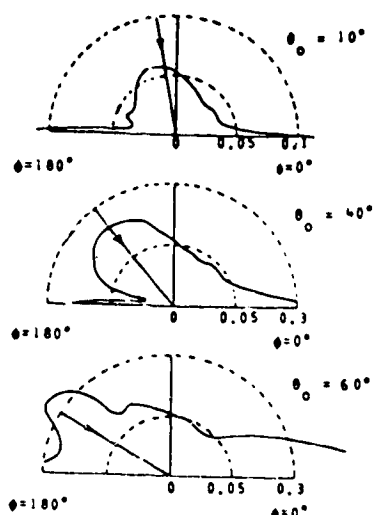


Figure 2: BRDF slices as angular signatures for pasture at 520 nm in the principal plane for 3 different solar illumination angles of 10, 40, and 60 degrees.

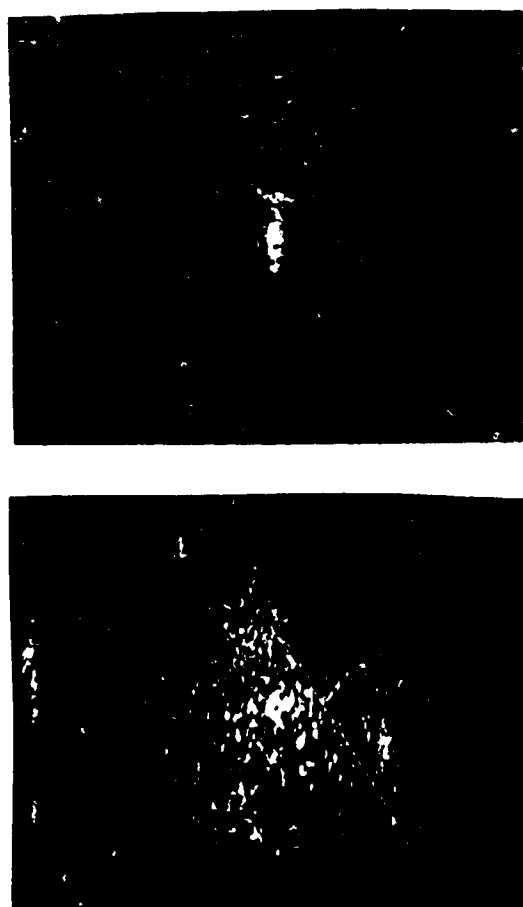


Fig. 3: The Canopy Hotspot photographed from about 300m altitude, over grass land (top photo) and coniferous forest (bottom).

Hot spot angular distribution measurements have been reported from aircraft data [4] and [5], but not from satellites. In fact, most scanning satellite detectors are excluding the hot spot direction from their field of view.

A SPACE-BORNE HOT SPOT MEASUREMENT CONCEPT

Taking hot spot data from an aerial platform with an imaging camera is fairly simple as is demonstrated by the photographic images. Recently, large goniometers have been used at the Joint European Research Center in Ispra, Italy, and at the Changchun Institute of Optics and Fine Mechanics in China, to perform laboratory measurements of complete BRDF's of small patches of vegetation targets. In every case the almost unlimited pointing capabilities of these instruments and platforms have been exploited, which is not a given for today's space-based sensors. Two fundamentally possible conical scanning techniques that allow hot spot angular signature measurements have been described in [2] and [6] and are graphically summarized in Fig. 4. Replacing the solar illumination with an active and pointable illumination source allows us to present a new concept enabling space-borne measurements of hot spot angular signatures.

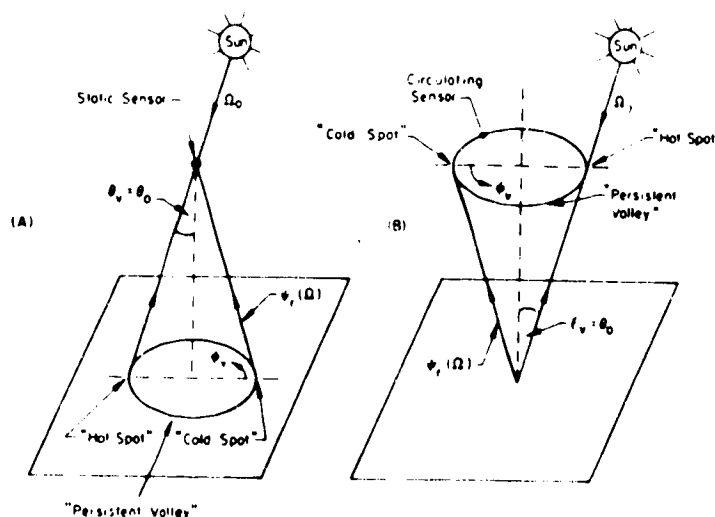


Fig. 4: Two possible conical scan patterns that allow hot spot angular signature measurements.

Our new concept for canopy hot spot measurements from space envisions active illumination and bistatic detection that would allow hot spot angular distribution measurements from space in a search light mode. The concept includes a pointable illumination source, such as a laser, coupled with a number of high spatial-resolution detectors that are tethered to the source and are rotating around the illumination source receiving photons nearly

coaxial with the retroreflection direction, see Fig. 5. This measurement concept is an extension to the conical scan pattern described in [6] and depicted on the right side of Fig. 4; it will allow measurements of the intensity wings of the hot spot angular distribution, especially its angular width.

Tethered satellite systems have been tested in recent space shuttle missions [7], demonstrating the technical viability of up to 20 km long tethers operating in space. A circular path of the illuminating laser circulating around the sensor (or vice versa) at a radius of 20 km at a nominal satellite altitude of about 500 km above the earth will allow the hot spot angular distribution to be investigated out to about 5 degrees full angle, which is sufficient to characterize most agriculturally important vegetation by its hot spot angular signature.

The illumination wavelength has to be selected so as to minimize atmospheric interference, i.e. within the atmospheric transmission windows in the near infrared, or the 8 to 14 micrometer IR region. Such selection will make night-time observations possible, which will increase the signal-to-noise ratio due to reduced or nearly eliminated solar background radiation. Since the tethers can be made of conducting material, they can be used to carry control signals between the illumination and sensor components to direct the laser beam and the look angle so that they cover the same area on the ground. Orienting the direction of both components simultaneously would allow the entire system to function like a search light, providing it with almost unlimited pointing capabilities. Engineering systems analyses and feasibility studies have yet to be performed.

CONCLUSIONS

Angular signature measurements can provide information about vegetation surfaces, e.g. about their canopy architecture, which is not otherwise accessible by today's remote sensing methods. A new concept is presented that may allow angular signature measurements from a space-borne platform involving active laser illumination, bi-static observation, and would operate at night. Potentially most useful applications of the concept are to measure canopy hot spot parameters from space. Hot-spot angular signatures are expected to be quantified and parameterized in sufficient detail to extract relevant information content on plant architectures.

The HOT-SPOT SEARCH LIGHT

SATELLITE CONCEPT

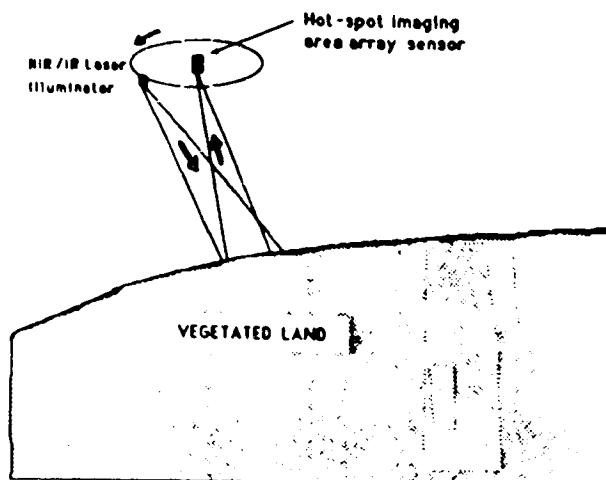


Fig. 5: The Hot-Spot Search-Light Concept for Angular Signature Measurements from Space.

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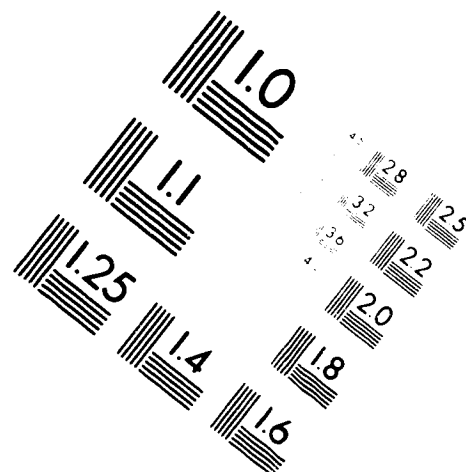
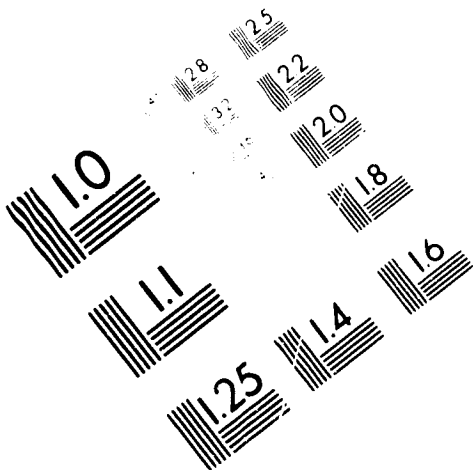
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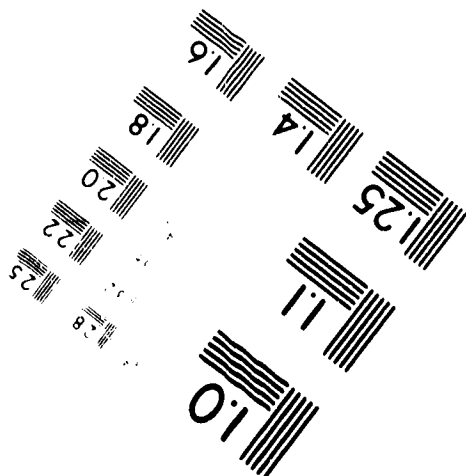
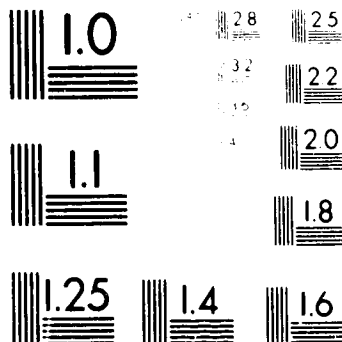
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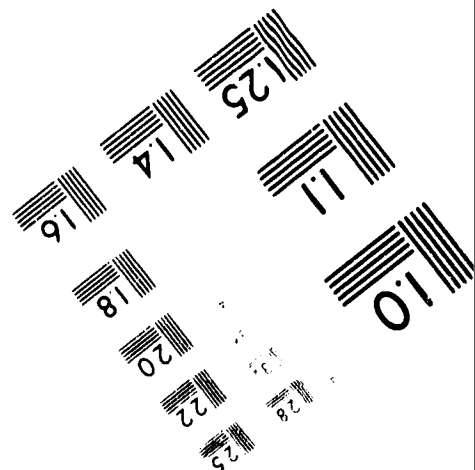
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